

An Electrical Method for the Combustion of Organic Compounds.

DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF
THE JOHNS HOPKINS UNIVERSITY IN CONFORMITY
WITH THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY.

BY

LEVI S. TAYLOR.

1905.

EASTON, PA. :
ESCHENBACH PRINTING COMPANY.

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CONTENTS.

Acknowledgment	4
I. Historical	5
II. The Electrical Method	6
Apparatus Required	6
The Platinum Coil	7
Gases Used for Combustion	8
The Porcelain Tube	8
Platinum Disk	11
Electrical Energy Used	11
Volatilization of Platinum	12
Objections to Closed Combustion Tube	12
The Open Tube	13
III. Combustion of Compounds Containing Carbon and Hydrogen with or without Oxygen	13
Analyses of Sugar	13
" " Naphthalene	15
" " Benzene	15
IV. Combustion of Nitrogen Compounds	15
Analyses of Urea	16
" " Uric Acid	16
" " Orthonitrophenol	17
" " Metadinitrobenzene	17
V. Combustion of Halogen Compounds	17
Analyses of Dibrombenzene	18
" " Chloral Ethylate	18
VI. Combustion of Sulphur Compounds	19
Analyses of Diphenylsulphone	19
" " Orthobenzoyldiphenylsulphone	20
VII. Determination of Sulphur	20
VIII. Biographical Sketch	21

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An Electrical Method for the Combustion of Organic Compounds.

When Liebig,¹ in 1831, announced his method for the determination of carbon and hydrogen in organic compounds, chemists recognized its importance at once. Since that time many alterations in the original method have been devised but the essential principle, namely the burning of the substance by oxygen and copper oxide, has not been supplanted.

With the introduction of illuminating gas into the laboratory, new and better means of heating became available and the charcoal furnace was replaced by one using gas for its heating power. The development of the latter we owe chiefly to Hofmann,² Erlenmeyer,³ and Glaser,⁴ although many others have offered slight improvements.

In more recent years, with the rendering applicable of the electric current to laboratory work, many attempts have been made to use its well-known heating power to bring about the combustion. It has, however, been a difficult problem to obtain some permanent cheap conductor having the desired properties. In the substance *krptol*⁵ its solution has been more nearly reached. This substance possesses the essential element of cheapness but the amount of electrical energy required to furnish sufficient heat for a combustion is very large. Further, an especial apparatus has to be constructed for its use, costing as much as the gas furnace.

The peculiar power of platinum to act as a catalytic agent, causing the combustion of vapors passed over it, is well known and led Kopfer,⁶ as early as 1876, to attempt combustions by its use in place of the copper oxide. Although the results he obtained were very satisfactory the amount of platinum wire

¹ Pogg. Ann., **21**, 1 (1831).

² Ann. Chem. (Liebig), **90**, 235; **107**, 37.

³ *Ibid.*, **139**, 70.

⁴ *Ibid.*, Suppl., **7**, 213.

⁵ Kryptol Gesellschaft, M. B. H., Berlin, N. W. 7.

⁶ J. Chem. Soc. (London), **29**, 660 (1876).

and platinum black which he found necessary made the cost too great for the general introduction of the method. More recently Dennstedt¹ has devised a process for the burning of organic substances by the use of platinized quartz. In this the amount of platinum required and the heat used are very small but even with the most careful work the results obtained are not always satisfactory.

The process for the analysis of organic compounds, which is here described, has been in general use in this laboratory during the past year and with such satisfactory results that it has almost wholly supplanted the older method of burning organic compounds. It has already been applied to the combustion of hydrocarbons and their oxygen, nitrogen, halogen and sulphur derivatives. The advantages which it has been found to possess, over the usual method, are the following: (1) The apparatus required is so compact and of such small dimensions, that the combustion can be made at the working table of the student; (2) the waste of energy is much smaller; (3) the time consumed in preparing for and in making a combustion is considerably diminished; (4) much greater ease in regulating the combustion is possible.

Fig. I. represents the apparatus in its simplest form. The thin glass combustion tube *a* is closed at one end and has a length of 350 mm. and an internal diameter of 15 mm. Through the rubber stopper in its open end there pass: (1) the porcelain tube *c*, which has a length of 250 mm. and a diameter of 6 mm.; (2) the glass tube *k*, through which the products of combustion enter the absorption apparatus; (3) the rather stout platinum wire (No. 18 B & S gauge), which extends from *f* to *j*. The porcelain tube *c* is joined outside of the stopper, by means of rubber tubing, to the branched glass tube *d*. The latter is provided with a stopper, *g*, through which passes the platinum wire *e* (also No. 18), which extends into the porcelain tube to the point *h*, where it is joined to a smaller platinum wire (O. No. 29, B & S gauge). The small wire has a length of about 1.75 meters and weighs, approxi-

¹ Z. anal. Chem., 41, 532; Ber. d. chem. Ges., 30, 1592. For fuller account see "Anleitung zur vereinfachten Elementar. Analyse," Hamburg, Otto Meissner, 1903.

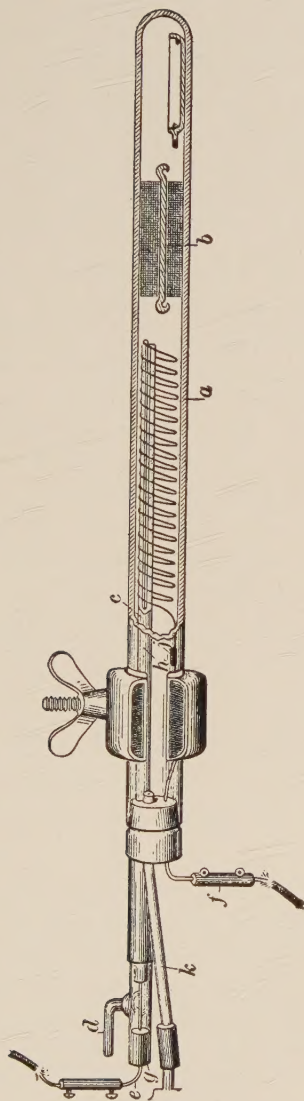


Fig. I.



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mately 2.5 grams. It extends, from its junction with the larger wire at *h*, through the porcelain tube to the inner end of the latter and then returns on the outside, in a series of suspended coils, to the point *j*, where it joins the larger wire *f*. Thicker wire is used from *f* to *j* and from *e* to *h* in order to avoid any overheating of the rubber stopper by the current. The roll of copper wire gauze *b*, about 60 mm. in length, is inserted between the end of the porcelain tube and the boat containing the substance to be burned.

The coil is prepared by first heating the wire, while stretched slightly, either by passing it through a flame or by connecting its ends with electric terminals and passing a current through it. The danger of the former method, which is obviated by the latter, is that the wire will have its resistance changed at some one spot by being drawn out there through uneven heating. This also serves the purpose of straightening the wire and removing some of the temper, making it easier to wind. It is then wound upon a screw thread of such size that the coil will have an approximate diameter of 9 mm. During the winding the tension of the wire should be kept as nearly constant as possible. After all the wire has been placed upon the thread it may be easily removed by turning the screw, the wire being held firmly by the fingers. From this method an even coil should result which is ready to be placed upon the porcelain stem for use. After the wire has been used for a few combustions it loses its temper and the coil can then be reformed by simply winding it around a glass rod of the proper diameter.

The heavy wire from *j* to *f* is sharpened at one end and with a pair of forceps forced through the rubber stopper. By regulating its length inside the combustion tube the coils may be brought so near the end that all the moisture will be driven over and yet not near enough to burn the stopper. The longer wire from *h* to *e*, forming the second terminal, is passed through the stopper in the branched tube *d* at *g* and the end of the tube filled with sealing-wax. The second end of the branched tube is slipped over the end of the porcelain tube and

closed with thick rubber tubing tied with waxed shoemaker's thread.

The oxygen or air which is used in the combustion is purified by passing it through a strong sulphuric acid solution of silver sulphate, then over soda-lime and lastly over calcium chloride. It enters the apparatus at *d* and while passing over the portion of the small wire which is within the porcelain tube has its temperature raised more or less according to the rate of its flow. It is, therefore, already hot when it enters the tube *c*, where the combustion is to be effected. The completeness of the combustion is, probably, due, to a large extent, to the temperature to which the oxygen is heated before it comes in contact with the vapors to be burned. This hot oxygen is also of especial advantage not only in keeping the roll of copper gauze next to the porcelain tube thoroughly oxidized at all times, but in heating the roll to such a temperature that it can be acted upon readily by the vapors of the substance to be burned. The excess of oxygen and the products of the combustion of the substance pass together over the heated coils on the outside of the porcelain tube, completing the burning of any unoxidized material coming from the rear.

In the earlier work with this apparatus stems of long clay tobacco pipes, were employed to support the coils but, owing to the highly porous character of this material, it was found necessary, in order to obtain satisfactory determinations of hydrogen, to dry out the tube each time before beginning a combustion. Afterwards these pipe stems were replaced by unglazed porcelain tubes, which were made at the Royal Berlin Porcelain Works. These have proved very durable and they are not, of course, hygroscopic to an appreciable degree. None of these porcelain tubes has yet cracked, though some of those in use have served for more than a hundred combustions.

The roll of copper wire gauze, *b*, is not absolutely necessary where the substances to be burned do not readily yield explosive mixtures with oxygen and, in the earlier work, it was omitted. Its presence is, however, of some advantage because much less care is required in the management of the combustion with

it than without it. If the substances are liquids, or if they readily yield large quantities of inflammable vapors when heated, the roll of wire gauze must be inserted between the material and the end of the porcelain tube through which the oxygen enters. There is one, and only one, objection to its use, and this is that the flow of oxygen or air must be continued for some time after the completion of the combustion, in order to insure the removal of all of the carbon dioxide and water from the space occupied by the boat.

The combustion is conducted in the following manner: Having placed, in the positions indicated in the figure, the boat containing the material and the roll of copper wire gauze (which, in the beginning, may or may not be oxidized) and having joined the tube *k* to the usual train of absorption apparatus, a slow current of dry and purified oxygen is admitted and the electric circuit is closed through a regulating rheostat. Starting with a current of about 1 ampere the flow is gradually increased, at the rate of 0.2 ampere every 2 or 3 minutes, until the coils assume a bright red color or if No. 29 wire is used until 3.6 amperes are reached. While the coils are being heated a lamp having a broad, thin flame is brought under the roll of copper wire gauze and raised gradually until the blue portion of the flame touches the glass tube on its under side. The substance in the boat is then heated with the same lamp, or with another which is held in the hand. The rate of heating and the flow of oxygen are so regulated with respect to each other that at least one-half of the roll of wire gauze is kept in the oxidized condition during the entire combustion. After the formation of volatile products has ceased, the reoxidation of the copper progresses rapidly and the oxygen enters the rear compartment, burning any residue of carbon upon the boat or upon the glass.

Having finished the combustion of the substance, the current of oxygen is replaced by one of dried and purified air, and the flow of the latter must, of course, be continued until the products of combustion have all been expelled from the space behind the wire gauze. It is here that a miscalculation is likely to be made. The time required for the complete removal of these

products depends, principally, upon the freedom of diffusion through the gauze and for this reason it should not be rolled too tightly.

The apparatus, as already described, is adapted to the combustion of those solids and liquids which consist of carbon and hydrogen, or of carbon, hydrogen and oxygen.

The heating of the roll of wire gauze *b*, and, at times, of the substance also, is facilitated by inverting over the tube, at a little distance above it, a trough of asbestos board, the side of the trough, at the back, being much deeper than in front. This arrangement is supported in its position by a rod, which is inserted in a heavy block, resting upon the work table behind the tube. The device is also of advantage in protecting the tube from draughts of cold air during the combustion and during the subsequent cooling period. The portion of the glass tube which is occupied by the porcelain tube and the platinum wire is protected, on the bottom, by a semi-circular strip of asbestos board which is inserted in the clamp between the lower jaw and the glass. To protect the upper portion of the tube in the same region, a semi-circular trough of mica is inverted over it, behind the clamp, in such a manner that the lower edges of the mica rest in the asbestos trough below. The mica is made to keep its curved form by fastening it to narrow strips of metal and bending the latter to the required shape.

The cooling of the tube requires some care. The current should be reduced quite gradually, following the reverse of the heating process, and it is well, also, as soon as the combustion is finished, to cover the portions of the glass tube which is beyond the porcelain one with the soot from a smoky flame and to take any other measures for the protection of the tube which will contribute toward the proper annealing of the glass. Care must likewise be taken never to allow the platinum coils to come in contact with the glass either while heating or cooling the tube, since, in the former case, the metal is likely to stick to the glass, while, in the latter, the tube is quite sure to crack at some lower temperature. Further, the coils, after being used for some time, show a tendency to increase in size towards the inner end of the porcelain

tube and, if they approach too nearly the internal diameter of the combustion tube, the wire must be taken out and rewound. The difficulty of keeping the coils away from the glass while they were hot, led to the placing upon the inner end of the porcelain tube of a small platinum disk. The porcelain tube was ground down at the end until it was practically square and the disk, which was a little smaller than the internal diameter of the combustion tube, was fitted eccentrically upon it so that the coils were held the same distance from the glass tube at all points. Small holes were drilled in the disk to allow the free passage of the vapors. As the small wire of the coils only comes in contact with the platinum disk at one point it does not heat the latter hot enough to affect the glass tube injuriously. The porcelain tube and coils are thus always kept in the same relative position to the glass tube while the combustion is not in any way interfered with. With the proper care a good piece of glass tubing can be used for a large number of combustions. In one case 31 combustions were made with one tube before it broke and in several others about 20 were made. The period of service of the glass depends, however, upon protecting it from draughts while hot and a thorough annealing after each heating.

The time required for a combustion does not, ordinarily, exceed half an hour and it may be reduced to 20 minutes, or even less, if the substance to be burned is of such a character that the roll of wire gauze can be dispensed with. Its omission is not, however, recommended at any time, except to those who have had some experience with the method.

The consumption of electrical energy, for the length of wire used, is small, amounting to about 3.6 amperes at 54 volts (194.4 watts, or one-fourth of a horse-power) during the time when the highest temperature is maintained.

At the highest temperature employed during the combustion (at a bright red, but not a white heat), especially when the wire is new, there is a sensible volatilization of the platinum. This volatilization of platinum in an atmosphere of oxygen, even at comparatively moderate temperatures, has been repeatedly noticed by others. In one case, a platinum wire

weighing, in the beginning, 2.3446 grams was found, at the end of the thirty-eighth combustion, to have lost 0.1337 gram in weight. The volatilized metal settles upon the surface of the glass and porcelain tubes as a dark deposit which, at first, may be mistaken for carbon. The presence of such films of volatilized platinum upon the inner surface of the tube is, of course, by its catalytic action, of some assistance in the combustion.

The obvious objections to the use of the short, closed combustion tube represented in Fig. I. are the following: In the first place, whenever the boat is to be introduced or withdrawn, it is necessary to remove and reinsert the rubber stopper with the tubes and wires which pass through it and also the roll of wire gauze and, during such manipulation, the wire coils, which should be distributed uniformly along the porcelain tube, are easily displaced and may become entangled. Again, as previously mentioned, the flow of air must be continued for some time after the combustion is otherwise finished, in order to secure the complete removal of the carbon dioxide and water from the space occupied by the boat. These difficulties are wholly obviated by using a somewhat longer tube which is open at both ends, as represented in Fig. II. In this arrangement the boat is introduced from the rear and there is placed behind it a second roll of copper wire gauze, about 60 mm. in length. The stopper in the front end of the combustion tube, the forward roll of wire gauze, and also the apparatus as a whole, are never disturbed. Each roll of wire gauze is heated by a lamp giving a broad, thin flame and there is inverted over both rolls and the space between them the asbestos shield already described. The lamps should be raised until the bottom of the tube is just within the blue region of the flames. To prevent any sagging of the combustion tube while hot, it is supported at a point beneath the end of the porcelain tube by a forked or notched standard, which is placed under the asbestos trough in which the front portion of the apparatus lies.

The combustion is conducted in the same manner as in the short, closed tube, except that a slow current of oxygen

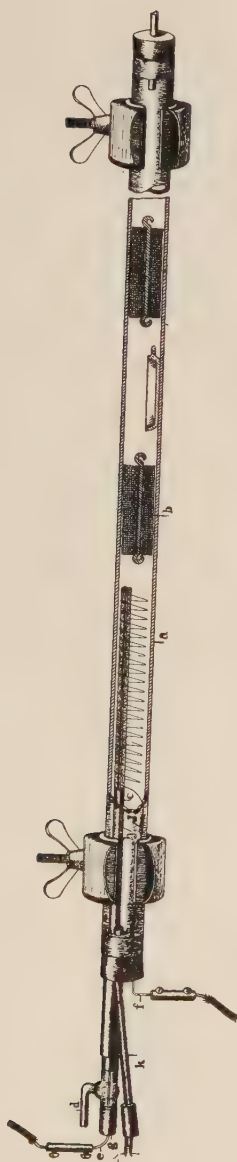


Fig. II.

or air is admitted from the rear during the entire experiment. This prevents any accumulation of volatilized matter in the back part of the tube and aids in the expulsion of the products of combustion from the space occupied by the boat.

If the substance to be burned is very volatile, it is advisable to introduce air and not oxygen in the rear and to employ, behind the boat, a roll of gauze which is only partially oxidized. In this way the vapors of the substance may be diluted with nitrogen to any desired extent.

With this apparatus a Marchand tube, filled with calcium chloride, is used to absorb the water vapors formed, because the end of the tube can be placed directly in the stopper of the combustion tube, thus doing away with the connecting tube *k*. No trouble is experienced with this arrangement in getting the water vapor ready to weigh by the time the combustion is completed. When the Marchand tube is removed from the absorption train its ends are closed by small pieces of rubber tubing carrying glass plugs.

The clamp at the rear is required only as a support and it should not grip the tube so tightly as to prevent the free movement of the latter, back and forth through the former.

In the following determinations of carbon and hydrogen in cane-sugar, which were made for the purpose of testing the method, the short, closed tube was employed and the roll of wire gauze was omitted. A clay tobacco pipe stem served for the introduction of oxygen and the effect of its use is evident in the high percentages of hydrogen which were obtained in the first four analyses. In the last two analyses, in which normal quantities of hydrogen were obtained, the pipe stem was thoroughly burned out in a current of oxygen before beginning the combustion:

Weight of sugar. Gram.	Carbon found. Per cent.	Hydrogen found. Per cent.	Time occupied in combustion, Minutes.
0.1364	41.95	6.86	25
0.1188	42.03	6.63	18
0.1227	42.03	6.65	18
0.1382	42.07	6.73	18
0.1154	42.11	6.47	18
0.2809	42.03	6.46	45
Theoretical,	42.09	6.47	

The current at the highest temperature was 2.6 amperes at 48 volts. In these combustions a coil of No. 32 wire (B. & S. gauge) was used but, as is stated later, it was found advisable to exchange this, in the combustions of naphthalene, for a greater length of larger wire.

Careful management is required, even in the combustion of such substances as sugar, when the roll of wire gauze is omitted. On several occasions, when it was attempted to reduce the time consumed in the combustion to 15 minutes or less, small explosions occurred. To test the completeness of the combustion a Geissler apparatus was filled with a very dilute solution of palladium chloride and placed on the end of the absorption train. Any incompletely burned material darkens this solution at once. To avoid the explosions, which always resulted in unburned material escaping, the combustion tube was lengthened slightly and the previously mentioned roll of wire gauze was inserted between the boat and the end of the porcelain tube. Combustions of toluene and two of naphthalene were made with the modified apparatus with the following results :

Toluene.

Weight of substance. Gram.	Carbon found. Per cent.	Hydrogen found. Per cent.	Time occupied in combustion. Minutes.
0.1057	90.91	8.62	35
0.0650	91.25	8.80	35
Theoretical,	91.24	8.76	

Naphthalene.

Weight of substance. Gram.	Carbon found. Per cent.	Hydrogen Found. Per cent.	Time occupied in combustion. Minutes.
0.1184	93.54	6.36	55
0.1252	93.49	6.39	55
Theoretical,	93.70	6.36	

During the first attempt to burn naphthalene a slight deposit of the substance collected in the front end of the tube. The length of the small platinum wire was increased by about 0.5 meter, making its total length about 2 meters. No further difficulty was experienced in effecting complete

combustions. With the lengthened wire, the electrical energy consumed, at the highest temperature, was 3.6 amperes at 65 volts. The wire was afterwards shortened until, with a current of 3.6 amperes, the fall in potential was 54 volts.

With volatile substances the only change necessary is a slight lengthening of the tube so that the space between the copper roll and the boat may be increased until but little heat is conducted along the tube.

The analyses of naphthalene and benzene, which follow, were made with the apparatus represented in Fig. II. :

Naphthalene.

Weight of substance, Gram.	Carbon found, Per cent.	Hydrogen found, Per cent.	Time occupied in combustion, Minutes.
0.1274	93.59	6.83	45
0.1340	93.50	6.80	30
0.1198	93.51	6.46	30
0.1249	93.57	6.36	35
Theoretical,	93.70	6.36	

Benzene.

Weight of substance, Gram.	Carbon found, Per cent.	Hydrogen found, Per cent.	Time occupied in combustion, Minutes.
0.0887	92.24	7.82	40
0.1474	92.28	7.80	75
0.1749	92.20	7.87	75
0.1334	92.18	7.66	75
Theoretical,	92.25	7.75	

The Combustion of Substances Containing Nitrogen.

For the determination of carbon and hydrogen in compounds containing nitrogen, there are placed in the combustion tube : (1) a roll, 100 mm. in length, of copper wire gauze which has been reduced in the usual way by methyl alcohol ; (2) a roll, 80 mm. in length, of wire gauze which has been well oxidized ; (3) the boat containing the substance ; (4) a short roll of wire gauze also well oxidized.

During the combustion each of the three rolls is heated by a burner giving a broad, thin flame, the last lamp serving also for heating the substance. The portion of the tube occupied

by the copper is covered with a screen of asbestos board, to insure a sufficiently high temperature for the reduction of the nitric oxide. The flow of oxygen through the porcelain tube is so regulated that only about one-quarter of the copper roll (1) is oxidized, while at the rear it is admitted as rapidly as may be necessary to keep a portion of the second roll (2) at all times in an oxidized condition.

No great difficulty has been experienced in successfully burning nitrogenous compounds, except in the case of nitro derivatives and even these gave good results after the practice was adopted of introducing into the boat, with the substance, a quantity of loose copper oxide or finely divided silica.

The silica offers an advantage in that one can tell, from its light color, when all the carbon has burned off. A small amount of it can be placed in the boat and left there from one combustion to another. These substances absorb the compound as soon as it melts and give off the vapors at a much more uniform rate.

By way of testing the applicability of the method to compounds containing nitrogen, analyses were made of urea, uric acid, orthonitrophenol and metadinitrobenzene. The results are given below:

Urea.

Weight of substance. Gram.	Carbon found. Per cent.	Hydrogen found. Per cent.	Time occupied in combustion. Minutes.
0.1237	19.87	6.79	60
0.1542	20.03	6.78	70
0.1569	19.90	6.78	60
Theoretical,	19.96	6.70	

Uric Acid.

Weight of substance. Gram.	Carbon found. Per cent.	Hydrogen found. Per cent.	Time occupied in combustion. Minutes.
0.1947	35.64	2.68	75
0.1738	35.60	2.68	75
0.1970	35.65	2.62	
0.1929	35.60	2.48	
Theoretical,	35.67	2.39	

Nitrophenol.

Weight of substance. Gram.	Carbon found. Per cent.	Hydrogen found. Per cent.	Time occupied in combustion. Minutes.
O. 2632	51.69	3.75	75
O. 1520	51.62	3.89	75
O. 1225	51.78	3.76	60
O. 1315	51.78	3.76	70
O. 1464	51.75	3.79	60
Theoretical,	51.77	3.62	

Dinitrobenzene.

Weight of substance. Gram.	Carbon found. Per cent.	Hydrogen found. Per cent.	Time occupied in combustion. Minutes.
O. 1152	42.75	2.61	90
O. 1435	42.70	3.02	120
O. 1441	42.67	2.62	105
O. 1174	42.72	2.78	120
O. 1462	42.73	2.72	120
Theoretical,	42.83	2.39	

The time consumed in the burning of these nitrogenous compounds, especially of the dinitrobenzene, was probably greater than necessary; but some earlier experiences had led to the conclusion that, in order to get a complete reduction of the nitric oxide, as much of the combustion as possible must be made to take place upon the oxidized roll (2) next to the boat.

For the combustion of these substances a tube about 650 mm. in length was used.

The Combustion of Halogen Compounds.

To prepare the apparatus for the analysis of substances containing the halogens, a piece of silver foil, about 50 mm. in width, is rolled up with a sheet of thick paper, which is afterwards withdrawn. The silver roll is placed in the tube quite close to the end of the porcelain tube and is not directly heated during the combustion. In other respects the arrangements are the same as for the combustion of non-nitrogenous compounds. A roll of well-oxidized copper wire gauze follows the one of silver, then the boat containing the substance and, finally, a second roll of oxidized copper wire gauze.

During the combustion there is formed a quantity of fusible cuprous-halogen salt, which deposits itself, more or less, upon the inner surface of the glass tube, but does not, at any time, get beyond the silver foil into the space occupied by the porcelain tube and platinum wire. On cooling, the cuprous-halogen salt, in accordance with the well-known behavior of such compounds, absorbs large quantities of oxygen, only to give it up again when the apparatus is reheated in a succeeding experiment. At the same time the copper wire, in the oxidized rolls, grows thinner and becomes quite brittle.

The quantity of the cuprous salt accumulates, after a few combustions, to such an extent that the time required for its oxidation is considerable. Hence, it is well frequently to cleanse the combustion tube and to renew, at the same time, the oxidized rolls of copper wire gauze.

The substances selected for the purpose of testing the applicability of the method to halogen compounds were dibrombenzene and chloral ethylate. The results are given below :

Dibrombenzene.

Weight of substance, Gram.	Carbon found, Per cent.	Hydrogen found, Per cent.
0.1245	30.62	1.85
0.1395	30.40	1.82
0.1319	30.33	1.75
0.0836	30.40	1.93
0.0745	30.42	1.81
Theoretical,	30.51	1.71

Chloral Ethylate,
 $\text{CCl}_3\text{CH}(\text{OH})\text{OC}_2\text{H}_5.$

Weight of substance, Gram.	Carbon found, Per cent.	Hydrogen found, Per cent.
0.1611	24.83	3.63
0.1765	24.90	3.64
0.1789	24.61	3.71
0.1570	24.73	3.83
Theoretical,	24.82	3.64

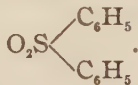
The time required for these combustions was from 30 to 45 minutes, depending upon the amount of substance burned. This time includes only that occupied by the actual burning of the substance, the time necessary to oxidize the cuprous halogen salt being independent of it. A tube about 600 mm. in length was used for these combustions.

The Combustion of Sulphur Compounds.

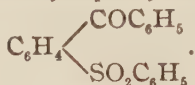
The determination of carbon and hydrogen in compounds containing sulphur presents no difficulty. A large number of such analyses have been made in this laboratory within the past year and the results have been quite as satisfactory as those obtained by the older method. The only change which it is necessary to make in the simple arrangement for non-nitrogenous and non-halogen compounds, in order to adapt the method to the combustion of sulphur compounds, is to substitute lead chromate for the roll of oxidized copper wire gauze which is nearest the end of the porcelain tube. Instead of maintaining the lead chromate in its position in the tube by means of plugs of asbestos or of wire gauze, it has been found more convenient and better for the glass tube to introduce it in the form of a cartridge. This is prepared by filling, with the loose, granular chromate, a shell made from very fine copper wire gauze.

The analyses of sulphur compounds were made with diphenylsulphone and orthobenzoyldiphenylsulphone as the material. The results are given below :

Diphenylsulphone,



Weight of substance. Gram.	Carbon found. Per cent.	Hydrogen found. Per cent.
0.1035	65.93	4.63
0.0997	66.00	4.70
0.1021	65.89	4.73
0.0961	65.98	4.53
Theoretical,	66.01	4.61

Orthobenzoyldiphenylsulphone,

Weight of substance. Gram.	Carbon found. Per cent.	Hydrogen found. Per cent.
0.0826	70.55	4.96
0.0908	70.58	4.45
Theoretical,	70.76	4.37

About 45 minutes were necessary to burn the substance in these combustions, after which the chromate had to be reoxidized in a current of oxygen. A somewhat shorter tube, 550 mm. in length, was used with about 85 mm. of its length filled by the chromate cartridge.

Determination of Sulphur.

An attempt has been made to apply this apparatus to the determination of sulphur in organic compounds. While the time available for this work has been too short for any definite results to be reached, the indications are that a very much more satisfactory method, than any of those now in use, can be worked out.

One peculiarity of this work is that the sulphur, when an excess of oxygen is present, is converted completely, in passing over the coils to the trioxide. It has been found very hard to absorb the sulphur trioxide in the condition in which it comes off the coils. Solutions of hydrogen peroxide, sodium hydroxide, and sodium peroxide have been tried as absorbents, but without satisfactory results. This peculiarity of the trioxide was first noted in the contact process for the manufacture of sulphuric acid. In this process, as it is in operation at present, 97 per cent sulphuric acid is used as the absorbent.

The difficulty of finding a satisfactory liquid led to an attempt to substitute for it a solid absorbent and along this line very promising results have been obtained. No definite conclusions can be given, however, at this stage, and work upon this method will be continued.

BIOGRAPHICAL.

Levi S. Taylor was born near Philomont, Loudoun County, Virginia, August 20, 1876.

He prepared for college at Abington Friends' School, Jenkintown, Pennsylvania. In the fall of 1895 he entered Swarthmore College, graduating in 1898 with the degree of Bachelor of Science. The next four years were spent as instructor of chemistry and physics in Friends' School, Wilmington, Delaware.

In October, 1902, he entered the Johns Hopkins University as a student in chemistry. In 1902-1903, and again in 1903-1904, he held a Virginia scholarship. In 1904-1905 he held a fellowship in chemistry at the University.

His subordinate subjects have been Physical Chemistry and Mathematics.

